ORIGINAL ARTICLES

Body Mass Index and Weight Distribution

CDR Pengelly[1], J Morris[2]

[1]Physician, 60 Manchester Road, Altrincham WA14 4PJ
[2]Head of Statistics, University Hospital of South Manchester

Abstract

It has been accepted for many years that being overweight or obese, as indicated by a body mass index (BMI) of 25 or over for the former and 30 or over for the latter, is associated with impairment of long term health and prognosis. The World Health Organisation (WHO) has indicated that, in Caucasians, waist measurements of 94cm or more in men, and 80cm or more in women have similar adverse effects on health, with increased risks at 102 cm or more in men and 88 cm in women.

The role of waist-hip ratio (W/H) and whether it represents a better index than waist (W) measurement alone is being debated; many papers favour waist measurement alone. But two papers in 2005 discussing 27,098 subjects, 12,461 of whom had myocardial infarction and 14,637 controls, come down firmly in favour of W/H and were followed by a Lancet Editorial entitled 'Farewell to Body Mass Index?'

Life assurance companies at medical examination usually request height and weight measurements (and therefore BMI). Most ask for waist measurements and a few hip measurements in addition (and therefore W/H).

The authors have reviewed the data in 816 consecutive subjects for life assurance examination in whom BMIs, Ws and W/Hs were all recorded. In these the evidence supports the use of W as the best indicator of risk in men (634 cases), but not in the relatively small number of women (182 cases) in whom H appeared better.

We believe that BMI, W and W/H should be recorded in every subject at life assurance examination so that the insurance companies in the long term will be able to reach valid conclusions about their individual and collective value.

Competing Interests: None

Key Words: Life Assurance, Body Mass Index, Waist Circumference, Waist-Hip Ratio.

Abbreviations: Body Mass Index: BMI, Waist Circumference: W, Hip Circumference: H, Waist-Hip Ratio: W/H, Spearman's Correlation Coefficient: r_s, Standard Deviation: SD, Department of Health: DOH.

Introduction

It has been recognised for many years than increasing body weight, as indicated by Body Mass Index (BMI) is associated with a higher mortality.[1,2] More recently the importance of body shape, indicated by waist measurement (W) and waist-hip ratio (W/H) has been noted.[3,4] Body shape has been described as 'apple' shaped (bad), and 'pear' shaped (good). [5,6]

The global epidemic of obesity has been noted by the World Health Organisation (WHO),[7] and the impact of obesity on mortality trends in a paper from a large insurance company.[8] Life assurance companies are becoming biased against severely overweight and obese subjects, a fact noted in the Sunday press.[9]

What is the evidence for the individual value of BMI, W and W/H?

Body Mass Index

BMI is calculated by dividing the bodyweight in kilograms by the height in metres squared. Thus theoretically the BMI is independent of height and represents body mass alone.

The World Health Organisation (WHO) classifies BMI as follows:-

Below 18.5 as 'underweight', 18.5-25.0 as 'healthy', 25-30 as 'overweight', and over 30 as 'obese', and have sub-divided the obese category as class I (30.0 to 34.9), class II (35.0 to 35.9) and class III > 40.10 Increasing risk of disease as the BMI levels rise have also been noted by others.[11]

BMIs of 40 or over are sometimes referred to as indicating 'extreme' or 'morbid' obesity.

The adverse effect on mortality is well shown in a figure in the account by Baird.[1] The data for the figure were acquired from an earlier paper.[2] There is abundant evidence that the average BMI is increasing in the UK and the first author published his own data from 1989 to 2001 (535 men and 159 women) showing an increase in BMI of 5.9% in the former and 12.8% in the latter. Parallel data from the Department of Health (DOH) using many thousands of subjects were quoted which showed an increase of 4.7% in both sexes.[12]

One obvious limitation of the value of BMI is that it does not distinguish between fat and muscle. Very muscular subjects, eg. rugby players and other trained athletes, can have BMIs of up to 32 not related to fat accumulation.[13]

Waist Measurement:

It has been known for many years that a waist measurement

greater than the expanded chest circumference has an adverse effect on prognosis.[1] The first author concluded that waist circumference was excessive if over 85cm (33") in a woman and over 100cm (39") in a man.[14] These measurements are more than those accepted in the WHO report[10] which gives >80cms for women and >94 cms in men, and these are the data also given in a survey of waist measurement related to BMI and waist-hip ratio in 904 men and 1014 women;[15] the authors believing that waist measurement alone is a better indicator of risks to health than BMI.

A further survey of 2836 men and 2698 women aged 50–59 concluded that larger waist circumference identifies people at increased cardiovascular risk.[16] There are those who believe that Waist-Height Ratio is particularly valuable[17] and clothing size has been used by others as an indicator of adiposity, ischaemic heart disease and cardiovascular risk.[18] The survey in 2004 in a large series of subjects concluded that waist measurement was a better indicator of risk than waist-hip ratio[8] and these authors also believe that waist measurement alone is a better indicator of risks to health than BMI.[15]

Waist-Hip Ratio (W/H)

W/H is another way of showing the amount of abdominal fat. The WHO report says this should be no more than 0.85 for a woman and 1.0 for a man.[10] It is possibly a better indicator of cardiovascular risk and death. The ratio was enthusiastically welcomed in the early 1980s in the two papers from Sweden.[3,4] However, since then, not all papers have favoured W/H above simple waist measurement (W).[19,20,21,22,23,24,25] In 2005 the Interheart study which looked at 27,908 subjects, 12,461 with myocardial infarction and 14,637 controls, has shown that W/H is the best indicator of risk for this condition.[26,27] The authors found the median W/H to be 0.93 in the cases of myocardial infarction and 0.91 in the controls.[27] The second paper[27] stimulated an editorial comment in the Lancet entitled 'A farewell to Body Mass Index?'[28] Despite the evidence of the above recent papers,[26,27] opinion is still divided about the value of W/H as a risk factor.[5,29] Hip circumference measurements are thought to be related to muscle mass.[29]

The first author has been taking Waist and Hip measurements (and therefore W/Hs) since 1993 and a series of 177 subjects was published in 1996.[30]

We thought it would be of value to bring this study up to date and have reviewed a total of 816 subjects which includes the original 177.

Subjects and Methods

Patient Characteristics

This consisted of 816 subjects referred to the first author by insurance companies for medical examination between May 1993 and August 2004. All subjects were included and none were rejected. All were long term residents in the UK and the vast majority were Caucasian, though a very few subjects of native Asian and African origin were included. Details of the cohort are shown in Table I. This includes the 177 subjects previously reported in 1996.[30]

Height and Weight

These were recorded as in 1994[14] without shoes in both sexes and without jackets in males. Allowances for remaining clothing were 4 lbs in males and 2 lbs in females.

Height measurements were taken with a wooden Stadiometer, recorded to the nearest 0.5 in and converted to the nearest cm. Accuracy was maintained by periodic checking with a metal tape measure.

Weight was recorded in stones and pounds with a beam apparatus (known as a personal steelyard type). This was periodically checked by the current representatives of the manufacturers, the latest check being in December 2007 when it was accurate to 0.25 lb. Measurements were recorded to the nearest 0.5 lb and then converted into metric measurement to the nearest 0.1 kg.

Table I: Details of Cohort

Year	All subjects			Males			Females		
	Number	Mean age (yrs)	Range (yrs)	Number	Mean age (yrs)	Range (yrs)	Number	Mean age (yrs)	Range (yrs)
1993 (part)	47	43.8	22 - 65	34	44.0	24 - 62	13	43.1	22 - 65
1994	80	43.7	22 - 73	63	45.0	22 - 73	17	39.2	23 - 68
1995	78	44.2	17 - 69	59	44.2	17 - 68	19	44.3	26 - 69
1996	83	46.3	22 - 73	62	46.9	25 - 67	21	44.4	22 - 73
1997	57	44.3	21 - 70	44	45.4	21 - 70	13	40.5	25 - 52
1998	81	44.5	24 - 69	67	44.5	24 - 68	14	44.6	26 - 69
1999	83	45.0	23 - 70	70	45.3	24 - 68	13	43.5	23 - 70
2000	65	44.3	25 - 72	52	46.5	31 - 72	13	35.7	25 - 52
2001	53	43.4	26 - 69	43	43.6	29 - 69	10	42.5	26 - 66
2002	66	46.4	25 - 74	48	46.8	29 - 72	18	45.2	25 - 74
2003	69	50.1	26 - 81	54	48.9	26 - 81	15	54.5	32 - 78
2004 (part)	54	47.3	27 - 66	38	47.6	27 - 66	16	46.6	27 - 63
ALL	**816**	**45.3**	**17 - 81**	**634**	**45.7**	**17 - 81**	**182**	**43.9**	**22 - 78**

Table II: Correlations (r_s) of Body Mass Index (BMI) with Waist (W)

Subjects Examined		BMI to W		BMI to W/H		Significance of difference between BMI to W and BMI to W/H
	N	r_s	p	r_s	p	p
All Subjects						
Total	**816**	**0.79**	**<0.001**	**0.50**	**<0.001**	**<0.001**
Males	634	0.83	<0.001	0.56	<0.001	<0.001
Females	182	0.80	<0.001	0.31	<0.001	<0.001
Subjects with Risk Factors						
Total	**292**	**0.83**	**<0.001**	**0.49**	**<0.001**	**<0.001**
Males	242	0.84	<0.001	0.54	<0.001	<0.001
Females	50	0.74	<0.001	0.12	0.42	<0.001
Subjects without Risk Factors						
Total	**524**	**0.76**	**<0.001**	**0.48**	**<0.001**	**<0.001**
Males	392	0.81	<0.001	0.54	<0.001	<0.001
Females	132	0.82	<0.001	0.37	<0.001	<0.001

Waist and Hip Measurements

These were recorded as described in 1994[14] and 1996[30] respectively. We used the umbilical level for waist measurements as suggested in the first paper from Sweden[3] though we note that most authors subsequently have preferred the level half way between the lower ribs and ilac crest.[31] They were taken to the nearest 0.5 in with a standard inch tape periodically checked with a metal tape measure. The initial measurements were converted to the nearest cm. Waist-hip ratios were expressed to two places of decimals.

Risk Factors

We decided to classify the subjects into two groups. Group 1 without risk factors and group 2 with risk factors viz. known hypertension (with or without anti-hypertensive therapy), an initial BP greater than 150/90 mmHg, those with coronary heart disease, diabetes mellitus (types I and 2); also including those with unexplained glycosuria or proteinuria.

Group 1 consisted of 529 subjects: 392 males and 132 females.

Group 2 consisted of 292 subjects: 242 males and 50 females.

These are shown in Tables II and III.

Table II

This shows the correlation coefficients (r_s) of BMI to W and BMI to W/H in all subjects and in males and females separately. It also shows the same comparisons in those with and without risk factors (groups 1 and 2 respectively).

All the differences between the correlation coefficients of BMI to W and BMI to W/H were highly significant ($p < 0.001$) except between BMI: W/H in females with risk factors ($p = 0.42$), but the number of subjects was small (50).

In all the subjects the correlation coefficients were higher with BMI to W than with BMI to W/H and these differences were highly significant ($p < 0.001$).

Table III

This gives an analysis of the means and SDs of the BMIs, Ws and W/Hs for the whole cohort and males and females separately, divided into those without risk factors (group 1) and those with risk factors (group 2). All the results were greater in the 'at risk' (group 2) subjects than in the 'not at risk' (group 1) subjects and these differences were all highly significant ($p < 0.001$) except in the relatively small number of females (total 182: group 1: 132, group 2: 50). In these there were no significant differences in the BMIs and WHs between groups 1 and 2 in the females ($p > 0.05$), but the differences for W and H did reach significance ($p = 0.039$ and 0.021 respectively).

Logistic regression analysis was applied to identify the best single independent risk factor. For the whole cohort and for males this was W: odds ratio 1.040 for the former ($p < 0.001$) and 1.045 for the latter ($p < 0.001$) and for females this was hip circumference (H): odds ratio 1.029 ($p = 0.024$). There were no significant differences in the BMIs, Ws, Hs and W/Hs between groups 1 and 2 in the females ($p > 0.05$).

We conclude that in our cohort of 816 subjects that the correlations of BMI to W were all significantly greater than those of BMI to W/H except in the small number of female subjects with risk factors, and that the differences between the correlations of BMI to W and BMI to W/H were also highly significant. Also that BMI, W and W/H were significantly greater in the 'at risk' subjects than in the 'not at risk' subjects except in the smaller number of females. W appeared to be a better predictor of risk than any other value measured except in females when it was H.

Table III: Data for 'Not at Risk' (group 1) and 'At Risk' (group 2) Subjects

Overall cohort (n=816)

	Mean (sd)		
	'Not at Risk' (n=524)	'At Risk' (n=292)	p value
BMI#	25.6 (16.4, 50)	27.2 (19.2, 51.9)	p<0.001
Waist	88.0 (12.1)	93.9 (12.2)	p<0.001
Hip	96.7 (9.6)	101.0 (10.0)	p<0.001
Waist : hip ratio	0.908 (0.063)	0.929 (0.058)	p<0.001

Males (n=634)

	Mean (sd)		
	'Not at Risk' (n=392)	'At Risk' (n=242)	p value
BMI#	25.8 (16.4, 50)	27.4 (19.2, 43.7)	p<0.001
Waist	90.8 (10.7)	95.9 (10.8)	p<0.001
Hip	97.9, (8.2)	101.5 (8.7)	p<0.001
Waist : hip ratio	0.926 (0.051)	0.943 (0.046)	p<0.001

Females (n=182)

	Mean (sd)		
	'Not at Risk' (n=132)	'At Risk' (n=50)	p value
BMI#	25.0 (16.5, 49.8)	26.0 (19.5, 51.9)	p=0.26
Waist	79.9 (12.6)	84.4 (14.3)	p=0.039
Hip	93.3 (12.3)	98.3 (14.4)	p=0.021
Waist : hip ratio	0.856 (0.068)	0.858 (0.061)	p=0.84

 # geometric means and ranges presented

Discussion

We have measured Body Mass Index (BMI), waist circumference (W), hip circumference (H) and calculated waist-hip ratios (W/H) in 816 successive subjects referred to the first author for life assurance medical examination between 1993 and 2004. We found good correlations between BMI to W and BMI to W/H ($p<0.001$) except between BMI and W/H in females with risk factors ($p=0.42$), but the number of subjects was small (50).

There was no selection of cases by us, but there could have been by the referring life assurance companies which might have requested medical examination on an excess of subjects with risk factors including obesity.

We divided the subjects into two groups – group 1 without risk factors and group 2 with risk factors. For convenience we used as risk factors known hypertension with or without anti-hypertensive therapy, an initial BP of more than 150/90 mmHg, evidence of coronary artery disease, diabetes mellitus types 1 and 2; we also included subjects with unexplained glycosuria and proteinuria.

Logistic regression analysis was applied to identify the best single independent risk factor. For the whole cohort and for males this was W but not for females which was H. The number of females was small (total 182: 'not at risk' 132: 'at risk' 50).

It has been accepted for many years that a raised BMI has an adverse effect on prognosis, especially if it is greater than 30[1,8,10,11] but since the early 1980s, body shape has been accepted as important.[3,4,5] This is determined by measurements of waist circumference, hip circumference and waist-hip ratio. Shape has been compared to apples and pears, the former being bad and the latter good. [5,6,9]

Whether BMI, W or W/H is the best indicator of risk continues to be debated. According to a number of studies, waist appeared to be winning as the best single measurement,[8,15,16,18] but two papers in 2005 (The Interheart Study),[26,27] based on a study of 27,908 subjects in 52 countries of whom 12,461 had a history of myocardial infarction and 14,637 were controls, showed W/H as the best indicator of risk. This gave rise to an editorial comment in the Lancet entitled 'Farewell to Body Mass Index.[28] Some authors believe that its conclusions are not entirely satisfactory,[29] but we believe that a study with such a large number of subjects deserves serious consideration. Mitka (2005)[3] does not consider the debate as concluded and, despite our findings in a relatively small number of subjects, neither do we. However, it is worth noting that the Interheart study was only concerned with subjects who had had an established myocardial infarction, which leaves the possibility that other conditions are not as closely associated with an increased W/H.

Few life offices actually ask for hip measurements, though most ask for waist circumference. We believe that all life assurance companies should have BMI, W and W/H recorded in all medical examinations so that in due course they will be able to clarify the risks indicated by all three individually and collectively.

Acknowledgements

We are grateful to Doctors Samuel Oleesky and Paul Miller for helpful criticism; to Miss Helen Carruthers, Medical Artist, for help in preparation of the Tables and to Mrs. Susan Alboutany for typing the manuscript.

References

1. Baird, I.M. in Medical Selection of Life Risks eds. Brackenridge R.D.C. and Elder, W.J. 4th edition. McMillan. London and Basingstoke (1998) pp 267-9.
2. Lew, E.A., and Garfunkel, L., Variations in Mortality by Weight among 750,000 men and women. Jour. Chronic Diseases (1979); 32: 563-76.
3 Larsson, B., Svardsudd, K., Welin, L. et al. Abdominal adipose tissue distribution, obesity and risk of cardiovascular disease and death: 13 year follow up of participants in the study of men born in 1913. Brit. Med. Jour 1984; 288: 1401-1404.
4. Lapidus, L., Bengtsson, C., Larsson, B.O. et al. Distribution of adipose tissue and risk of Cardiovascular disease and death. Brit. Med. Jour. 1984; 289: 1257 –1261.
5. Mitka, M. Obesity's role in heart disease requires apples and pears comparison. Jour. Amer. Med. Ass. 2005; 294: 3071 – 2.
6. Sattar N. and Lean M. eds.The ABC of Obesity. BMJ and Blackwell 2007. p 3.
7. World Health Organisation Report. Preventing and Managing the Global Epidemic (2000) WHO Geneva.
8. Eng, E. Too Big to Ignore: The impact of obesity on mortality trends (2004). Swiss Reinsurance Company, Zurich (2004).
9. The Observer Newspaper. Insurers Pile Pounds on the Overweight. Business and Media section January 1st (2006) pp 6 –7.
10. Op. cit. 7 pp 9-11 (Tables 2.1 and 2.2).
11. Kushner, R.F. and Blatner, D.J. Risk Assessment of the Overweight and Obese Patient. Jour. Amer. Dietetic Association (supplement) 2005; 53-62.
12. Pengelly, C.D.R., Increasing Body Weight. Jour. Roy. Coll. Phys, Edin., 2002; 32: 306-8.
13. Op cit. 6, p 4
14. Pengelly, C.D.R., Body Mass Index and Abdominal Girth in the Diagnosis of Obesity. Proc. Roy. Coll. Phys. Edin. 1994; 24: 174-8.
15. Lean M.E.J., Han, T.S. and Morrison, C.E., Waist Circumference as a Measure for indicating Weight Management. Brit. Med. Jour. 1995; 311: 158-161.

16. Han, T.S., van Leer J.C., Seidell, J.C., Waist Circumference action levels in the Identification of Cardiovascular Risk Factors; prevalence study in a random sample. Brit. Med. Jour. 1995; 311: 1401-5.
17. Hsieh, S.D., and Muto, T. The Superiority of Waist to Height Ratio as an Anthropometric Index to Evaluate Clustering of Coronary Risk Factors among Non-Obese Men and Women. Preventive Medicine. 2005; 40: 216–220.
18. Han, T.S., Gates, E., Truscott, E., et al. Clothing Size as an Indicator of Adiposity, Ischaemic Heart Disease and Cardiovascular Risks. Jour. Hum, Nutr., Dietet 2005; 18: 423–430.
19. Richelsen, B., Health Risks of Obesity. Significance of the Regional Distribution of Adipose Tissue. Ugeskr Laeger (Jour. Danish Med. Ass.). 1991: 153: 908–13.
20. Kalmijn, S., Curb, J.D., Rodriguez, B.L. et al. The Association of Body Weight and Anthropometry with Mortality in Elderly Men: The Honolulu Program. Int. Jour. of Obesity. 1999: 23: 359–402.
21. Falsom, A.R., Kushi, L.H., Kristin, E., et al. Associations of General and Abdominal Obesity with Multiple Health Outcomes in Older Women. The Iowa Women's Health Study. Arch. Int. Med. 2000: 160: 2117–28.
22. Welborn, T.A., Dhaliwal, S.S., and Bennett, S.A. Waist-Hip Ratio is the Dominant Risk Factor Predicting Cardiovascular Death in Australia. Med. Jour. Australia. 2003; 179: 580–585.
23. Ghosh, A., Bose, K., Chakravati, S., et al. Central Obesity and Coronary Risk Factors. Jour. Roy. Soc. Prom. Health. 2004; 124: 86–90.
24. Egger, G., The Case for using Waist to Hip Ratio in Routine Medical Checks. Med. Jour. Australia. 1992; 156: 280–285 .
25. Visscher, T.L.S., Seideu, J.C., Molarius, A., et al. A Comparison of Body Mass Index, Waist-Hip Ratio and Waist Circumference as Predictors of all cause Mortality among the Elderly: The Rotterdam Study. Int. Jour. Obesity 2001; 25: 1730–1735.
26. Yusuf, S., Ôunpuu, S. Hawken, S., et al. Effect of Potentially Modifiable Risk Factors associated with Myocardial Infarction in 52 Countries (The Interheart Study) Case Control Study. Lancet 2004; 364: 937–952.
27. Yusuf, S., Hawken, S., Ôunpuu, S. et al. Obesity and the Risk of Myocardial Infarction in 27,000 Participants from 52 Countries. A case control study. Lancet 2005; 366: 1640–1649.
28. Ragelund, C., and Omland, T. A Farewell to Body Mass Index? (editorial comment). Lancet 2005; 366: 1589–1591.
29. Op. cit. 6, p 5
30. Pengelly, C.D.R., Waist-Hip Ratios: Their Use in Life Assurance Examinations. Proc. Roy. Coll. Phys. Edin. 1996; 26: 224–228.
31. Op cit. 6, p 6